No Influence of Background Music on Face Recognition

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Statement of Sources

I declare that this report is my own original work and that contributions of others have been duly acknowledged.

Signed: ______________________ Date: 13/10/2018

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Abstract

Identifying methods to improve recognition memory for faces is valuable in a number of clinical and non-clinical applied situations. We investigated whether background music can improve face recognition through context reinstatement and the temporal parameters of this potential effect. We predicted that through multisensory processing of visual item information (a face) with rich auditory contextual information (music) a memory ensemble would form, thus creating an effective mnemonic cue. Participants were 19 females and 10 males, ranging in age from 19 to 47 years (M_{age} = 26 years, *SD*= 8). Participants were asked to remember faces in a study session with and without background music, then their memory was tested via a recognition test presented with the same music or with no music. Contrary to our predictions, we found no significant reinstatement-recognition benefits: There was no evidence to suggest that reinstating the musical encoding context at the face recognition test improved participants' ability to discern between previously seen and unseen faces. Future research needs to address the challenges specific to context-recognition memory and examine the boundary conditions that might lead to improvements in face recognition.

Our ability to recognise faces is important to many aspects of our lives. It helps us to identify individuals we do not know and recognise those that are close to us. Face recognition is a skill we mostly take for granted, but the recognition of familiar others has important evolutionary significance, as being able to distinguish between strangers and our in-group is fundamental to our successful interaction in the social world (Nelson, 2001). The value of the skill is indicated by our capacity to discriminate between even quite similar examples of face stimuli; remembering thousands of faces as unique (Werner, Kühnel, & Marowitsch, 2013). Beyond its foundational role in social interaction, face recognition plays a key role in a variety of applied settings (e.g., the identification of a culprit following a crime; Werner, et al., 2013). However, human face recognition performance is far from perfect, and identifying methods to modify memory and improve memory performance has particular value for individuals with impaired abilities to form new memories or recognise previously encountered people. For the growing number of individuals now suffering with dementia (Australian Institute of Health and Welfare, 2012), as the disease advances their ability to recognise their loved ones diminishes, which can lead to family breakdown, social isolation, and poorer health outcomes (Lavallée et al., 2016).

Research on background music as a therapeutic tool has revealed some success in improving aspects of cognitive performance in dementia patients, including recall from autobiographical memory (Fang, Ye, Huangfu & Calimag, 2017). For individuals with dementia, music can also improve attention and processing speed (Fang et al., 2017); factors important for memory function. As a therapeutic tool, music is appealing because it is easily available, non-invasive, and low in cost and negative side effects. However, no one has investigated whether music can be used to improve person recognition. If music is to have practical applications for improving memory performance, we must determine under which conditions music might facilitate memory. We investigated (a) whether background music can be used as a cue to reinstate the psychological context and neurocognitive processes engaged in during episodic memory encoding and improve face recognition, and (b) the temporal parameters of this effect.

Formatting, Storing, and Retrieving Memories

Episodic memory is our memory of personal experiences. Memory encoding converts information into a mental representation, which is stored in long term memory as a memory trace through the process of consolidation (Yonelinas, 2002). Episodic memory depends largely on the ability of retrieval cues to activate the relevant memory trace, which when triggered, imparts a sense of remembering (Tulving, 1985; Yonelinas, 2002). Our sense of remembering or familiarity reflects the activation of brain patterns that echo the original encoding of the event (Watrous & Ekstrom., 2014), and studies using functional neuroimaging have established that neurons or cell assemblies active at encoding are also active during retrieval (Gordon, Rissman, Kiani, & Wagner, 2013; Watrous & Ekstrom, 2014). The encoding specificity principle (Tulving & Thompson, 1973) posits that when focal information (e.g. an object, person, or event) is encoded into memory, the environment present at encoding becomes part of the memory trace for the item. Memory retrieval can be directed by external factors, such as the encoding environment, to recreate the specific neural patterns that occurred during the initial episodic encoding (Watrous & Ekstrom, 2014). Put simply, information from the environment present during encoding can function as a recall or recognition cue for that item at test.

Context-dependent Episodic Memory

Context reinstatement posits that we remember items better when we revisit the original learning context (Godden & Baddeley, 1975). Reinstating the original learning context triggers the original encoding neural activity, prompting the relevant memory into consciousness (Yonelinas, 2002). We experience the memory benefits of context reinstatement in our daily lives when we re-trace our steps to jog our memory. We can also mentally reinstate a place to help recall events (Smith-Spark, Bartimus & Wilcock, 2017). For example, having misplaced our keys soon upon arriving home, we might imagine our front door to mentally reinstate where we last used them. Reinstating the contextual environment, whether it be in mind or by physically returning to the front door, helps as a cue to activate the relevant memory trace. An understanding of the value of context reinstatement processes led to the inclusion of a context reinstatement technique in the cognitive interview (Fisher & Geiselman, 1992): The international gold standard in interviewing practice used by police to improve the amount and accuracy of information recalled by eyewitnesses.

Godden and Baddeley's (1975) classic study revealed that scuba-diving participants who learned words underwater recalled more of those words when tested underwater, than when tested on land. Conversely, words learned on land were better recalled when tested on land than underwater. The researchers concluded that the contrasting environments created strong context dependency for the learned material, and consequently, returning to the original learning environment acted as an effective mnemonic cue. The reinstatement of a physical environment to improve memory (i.e. environmental context-dependency) is the most studied aspect of context reinstatement (Smith & Vela, 2001). However, research has also tested context paradigms including, but not limited to, the investigation of context effects relating to an individual's olfactory (Ball, Shoker & Miles, 2010) and mood states (Balch, Myers, & Popotto, 1999). For example, Isarida et al. (2018b) found participants' ability to distinguish between previously seen words (old) and previously unseen words (new) was improved by reinstating contextual aromas (e.g. apple essence), while Balch et al. (1999) found evidence of pleasantness-dependent memory: Participants recalled more words when their feeling of pleasantness, manipulated by playing music, was reinstated.

Challenges for Recognition Memory

Context-dependent *recall* (i.e., the benefits of context reinstatement for recall) is generally accepted in the literature. However, studies investigating context-dependent *recognition* have produced mixed results (Smith & Vela, 2001). Godden and Baddeley (1980) adapted their earlier scuba-diving study to test for context-dependent recognition effects. In contrast to their recall memory findings, the environmental context manipulation that facilitated improved recall memory did not affect recognition memory.

Why might context effects be more robust for recall than recognition tasks? In a recall task, the participants are asked questions and must generate answers from memory. In a recognition task, participants are presented with one or more alternative answers and asked which, if any, they recognise. In face recognition tasks, participants generally study a series of faces and, after a retention interval, complete a series of test trials. For each test trial, a face is presented, and participants must judge whether the test face was in the studied list (i.e., is a target; old) or not (i.e., is a foil; new). For a standard recognition memory task (yes-no test), there are four potential outcomes (Figure 1). A 'hit' is a yes response to an old item, a false alarm is a yes response to a new item, a miss is a no response to an old item, and a correct rejection is a no response to a new item. In signal detection theory (Green & Swets, 1966) hit and false alarm rates reflect two factors; sensitivity (strength of feeling of familiarity) and bias (inclination to respond yes or no).

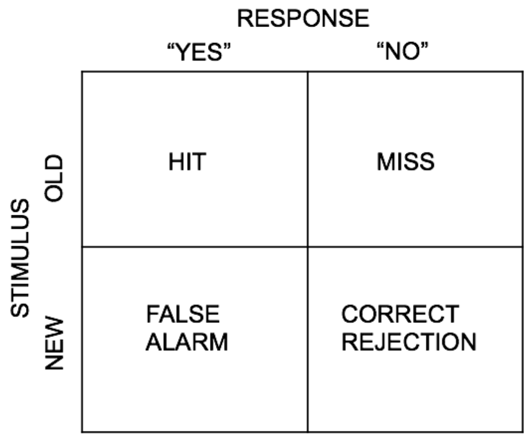

Figure 1. Stimulus-Response Matrix

In a face recognition test, the presence of a target face is in itself acting as a cue for memory retrieval; item information will match the target item regardless of contextual information, which reduces the effects of additional context cues (Murnane & Phelps, 1993). Russo, Ward, Geurts, and Schres (1999) found context-recognition effects on the number of words learned when reinstating background colours, but these effects were only observable when the words learned were initially unfamiliar and did not extend to familiar words. Vakil, Raz, and Levy (2007) reason that context effects only materialise in recognition studies for novel stimuli, as familiar items already have an existing representation and therefore establish a strong episodic trace during encoding, removing the necessity for context information (a phenomenon known as "overshadowing", Smith, 1994).

A further challenge for context-related recognition benefits is that reinstating a context can also strengthen a general sense of familiarity, potentially creating an illusionary sense of recognition for a previously unseen face in a recognition test (Murnane, Phelps, & Malmberg, 1999). This is because memorialised context information will match the reinstated context irrespective of whether the test item is new or old. Thus, reinstating an old context might increase correct identifications of previously seen items (hits), but also increase incorrect identifications of new items (false alarms) (Murnane & Phelps, 1993, 1995). In an applied setting, reinstating context (e.g. presentation of a photograph of the crime scene) might make it more likely an eyewitness will pick the true offender out of a line up (hit), but also more likely the eyewitness will pick an innocent person (false alarm) based on a misattribution of the context-related increase in familiarity. Any improved ability to identify the offender may be offset by an increased chance of a false identification. Consistent with this idea, Hockley (2008) found presenting study words on different coloured screens and then reinstating these colour conditions during the word recognition test increased both hit rates *and* false alarm rates. Therefore, context reinstatement does not necessarily increase discriminability in a recognition test.

In the context of a recognition test, discriminability (indexed by *d'* in signal detection theory (SDT) terminology) represents an increase in participants' ability to discriminate between tests items (e.g. faces) they have and have not seen before, and presents as an increase in the hit rate without an increase in the false alarm rate, or an increase in hit rate that outweighs any increase in the false alarm rate (Green & Swets, 1966). *Context-dependent discrimination* refers to the change in a person's ability to discriminate between targets and foils (previously unseen face) as a result of reinstating the original learning conditions at test (Murnane et al., 1999).

Reinstating context might be less effective for recognition memory, as the task is easier, and a cue is already present leaving less room for the contribution of the context cue. Further, context reinstatement might be detrimental for accurate recognition, due to the strengthening of general familiarity increasing the false alarm rate. Despite these plausible theoretical boundary conditions for context reinstatement benefits for recognition memory, and some variation in the findings of individual studies, Smith and Vela's (2001) meta-analysis found reliable context-reinstatement effects on recognition. Smith and Vela reported an average context-dependent recognition effect size of Cohen's d= .27 (classified as a small effect size), which was fairly consistent with those found in recall studies (Cohen's d= .29). Smith and Vela (2001) noted that the modest average effect size hides the fact that very large effects can also be found. However, they did not explain how they operationalised recognition performance; whether they used overall accuracy scores, hit rates (i.e., correct recognition without reference to effects on false recognition), a measure of discriminability that reflected both hits and false alarms (e.g., d'), or whether they simply took the effect sizes reported in previous studies with little consideration for the specific comparisons underlying these effects sizes. This makes it difficult to interpret the meaning and reliability of the meta-analytic result.

Context-dependent Recognition and ICE Theory

Despite the potential challenges outlined in the previous paragraph, there are some sound theoretical grounds for believing that context-reinstatement might improve discriminability, and for anticipating the boundary conditions for the effect. Murnane et al.'s (1999) ICE theory asserts the formation of *ensemble* information can explain how and when context-dependent recognition might occur. According to ICE theory, optimal recognition memory performance requires the encoding and activation of item (I), context (C), and ensemble (E) information. The ensemble is a unique representation of an event formed through the successful integration of item and context information. For example, a face (item) + background music (context) = unique face+music ensemble. Importantly, the ensemble is formed by the learner combining item and context information to create a new mental representation, distinct from the representations of the item and context information on their own. The ICE model predicts that if an ensemble has been formed through associative item-context encoding, then only hit rates should increase, producing increased discrimination. This is because the ensemble as a whole is distinct from the isolated item and context representations and should only match when the old item appears with the original context. Conversely, if an ensemble does not form then reinstating the context will activate general familiarity, potentially resulting in increased hits and false alarms. Thus, according to ICE theory, context-dependent benefits for discriminability rely on the effective formation of an ensemble (Murnane et al., 1999).

Murnane et al. (1999) proposed that context-dependent recognition (or discrimination) is further contingent on the complexity and meaningfulness of the contextual information. The researchers argued that complex contexts, as opposed to simple contexts, are more likely to bind with focal information to form an ensemble. Murnane and colleagues used the example of a colour background to represent a simple-visual context, and a photographic or illustrated background as a rich-visual context to demonstrate ICE theory. The prediction that contexts with more meaningful content (e.g., photograph background) increase context dependent discrimination has received some empirical support (Dougal & Rottelo, 1999; Hockely, 2008). More recently, Hanczakowski, Zawadzka, and Macken (2015) paired photographs of faces to specific background photographs (e.g. landscapes and buildings). Reinstating the original background photograph at test led to increased accuracy (discriminability) and greater confidence in participants' decisions in a forced-choice (i.e., choosing between two options) recognition test, than when faces were re-paired with different background photographs. Notably, Hanczakowski et al.'s use of visual stimuli (specifically, faces) stands in contrast to the more common use of words as item stimuli in context reinstatement studies. In sum, research suggests that the more intense and meaningful the environment, the more likely context-dependent effects are to emerge (Murnane et al., 1999).

Music as an Enriched Encoding Environment

Music offers a rich auditory environment that may act as a meaningful encoding context, and produce reinstatement-dependent recognition benefits (Isarida, Kabota, Nakajima, & Isarida, 2017). Smith (1985) found participants who listened to music while memorising words recalled more words two days later when the same study music was reinstated at test, compared with when the music was removed or changed. For those who learned words in silence, there was no advantage when music was played during the recall test. Thus, recall of verbal information was enhanced due to the reinstatement of the encoding environment. Similarly, Standing, Bobbitt, Boisvert, Dayholos, and Gagnon (2008) found participants in a "same-music" group (i.e., heard identical music at study and test) remembered more words at test than participants in a "changed-music" group (i.e., listened to different music at study and test). Other research on music context has investigated the reinstatement of musical characteristics and found tonality-dependent (major vs minor key) memory (Mead & Ball, 2007) and tempo-dependent (fast vs slow) memory (Balch & Lewis, 1996). Isarida et al. (2017) failed to find tempo or tonality-dependent effects but found a clear background-music-dependent effect: Participants recalled a higher proportion of words when music was reinstated at test, compared with no music. Ferreri, Bigand, Bard, and Bugaiska, (2015) revealed participants' verbal memory for the number of words recalled was improved (measured by the number of inter-item associations) when the music played at encoding was replayed at test. These recall benefits only occurred in music conditions and did not extend to other environmental auditory stimuli (e.g. natural rainforest sounds). Thus, music's ability to support the creation of inter-item associations between sensory information, and form meaningful ensembles, might be important to its success as an encoding environment and contextual cue for supporting retrieval.

Until very recently, research on context reinstatement using background music had focused solely on recall memory, with no research conducted on background music dependent recognition. Released this year, Isarida et al.'s (2018b) study presented participants with 40 words in intervals of 1.5, 2, 3, and 4 seconds while music played in the background. The researchers found a significant increase in the number of words recognised from a test word list when the original study music was replayed at test, compared with different test music. The increase in correct hits was accompanied by a significant increase in discrimination (*d'*), demonstrating that the reinstatement of the original music had increased the participants' ability to discern between old and new items. However, the beneficial effects of music only occurred for items that were presented for 1.5 and 2 seconds and revealed no effect for items that appeared for 3 or 4 seconds. A follow-up analysis established that recognition effect sizes decreased with study time. The researchers suggested that the strength of the item cue increased with the amount of time the item was studied, thus reflecting 'overshadowing' (i.e., suppressing the beneficial effects of the context cue). Nevertheless, Isarida et al. (2018b) demonstrated that the beneficial effects of background music for recall memory could extend to recognition memory. While these studies are encouraging, it is unclear whether background music-dependent effects generalises to the recognition of complex *visual* stimuli, such as faces. Improving our knowledge of if and when music enhances face and person recognition would have a variety of applied benefits.

Encoding, Processing, and Storage of Multisensory Information

The lack of research on background music-dependent effects on visual material is noteworthy, as different memory subsystems are active during the encoding and storage of verbal and non-verbal information (Baddeley, 2000). Baddeley and Hitch's (1974) multiple-component working memory model explains how we process different sensory stimuli. The model posits that sensory information is processed in two domain-specific subsystems; the phonological loop is responsible for the short-term maintenance of auditory information, while the visuo-spatial sketchpad maintains visual information (Baddeley & Hitch, 1974). These two systems are believed to be linked by the episodic buffer, which enables the interaction of sensory information in working memory (Baddeley, 2000). Busse et al.'s (2005) fMRI study recorded spreading neural activation that appeared to show auditory input providing temporal information to visual processing regions in the brain, and visual input providing spatial information to auditory processing. Thus, information arriving and cross-feeding from one modality interacts and influences sensory processing in other modalities (Quak, London, & Talsma, 2015).

The embedded-processing theory of working memory (Cowan, 1999) posits that, in working memory, the less similar the type of information or modality being applied, the easier it is to process that information simultaneously. Working memory capacity is higher (i.e. holding more items in mind) (Fougnie & Marois, 2009; Saults & Cowan, 2007) and recall performance is improved (i.e. number of items remembered increases; Delogu, Raffone, & Belardinelli, 2009) for cross-modal objects compared with modality-specific objects. Therefore, encoding faces (visual information in the visuospatial sketchpad) with music (auditory information in the phonological loop) might be less cognitively demanding than tasks where the item and context share the same processing modality (e.g., verbal[1] with musical information); again, suggesting music might be well-suited to provide contextual information for visual stimuli.

However, a meta-analysis on background music effects while learning revealed music can have detrimental, beneficial, or no effect on cognitive performance (Kämpfe, Sedlmeier, & Renkewitz, 2011) For example, Jäncke, Brügger, Brummer, Scherrer, and Alahmadi (2014) found no effect of vocal or instrumental music on the number of words recalled immediately, or two weeks after, memorising words. Whereas, Wilhelm, Hildebrandt and Oberauer (2013) found listening to music restricted how much and how well information was retained. Listening to music may be an unnecessary burden (Souza, & Oberauer 2016). However, the disfluency effect (Alter & Oppenheimer, 2009) is a metacognitive adjustment process where a person assigns cognitive resources according to their perception of task difficulty, thus assessing a task as more difficult

[1] Note that the written word is processed in the phonological loop due to sub-vocalisation (i.e. our 'inner voice') when reading.

can lead to the individual applying more cognitive effort (e.g. attentional resources) to compensate for task difficulty (Lehmann, Goussios, & Seufert, 2016). Therefore, background music might be considered a ‘desirable difficulty’ (Lehmann et al., 2016).

Response Bias in Recognition Decisions

Typically, when measuring memory performance, we are interested in effects on discriminability, but sometimes the factors that affect response bias are also of interest. More deliberative cognitive processing, reflecting increased task difficulty, can lead to more conservative responding at test (Benjamin & Bawa, 2004). Individuals make memory judgments not just on a feeling of familiarity, but also according to a decision criterion (Green & Swets, 1966). A recognition decision reflects the strength of evidence required to decide between ‘new’ and ‘old’. The placement of a decision criterion varies between individuals. Some people are liberal responders and are more likely to say “yes”, while conservative responders require a stronger feeling of familiarity before they are willing to say “yes” (Stanislaw & Todorov, 1999). Changes in experimental conditions can change participants’ response bias (Brown, Steyvers, & Hemmer, 2007) and a conservative shift-effect has been observed when a decision task is made more difficult (Benjamin & Bawa, 2004). Specifically, Benjamin and Bawa found that increasing task difficulty by manipulating item similarity during a recognition test led to participants adjusting to a more conservative criterion. Therefore, if participants apply more cognitive effort to compensate for increased task difficulty when music is played during encoding, they may also change their decision criterion to be more conservative during a recognition test when music is played. Thus, further to investigating context-dependency effects on discrimination, we investigated the effects of music at study and test on response bias.

When is memory amenable to context-dependent enhancement effects?

When assessing the potential application of music to improve face recognition, it is important to evaluate the boundary conditions for enhancement effects; that is, *when* memory might be sensitive to context-dependent memory enhancement. The malleability of memory is an important feature of our episodic memory system as it supports the prioritisation and awareness of significant life experiences (Ritchey et al., 2017). Our ability to consolidate information into long-term memory depends, not only on working memory processes, but also on sustained neural activity extending beyond the initial exposure of to-be-remembered information (Cohen et al., 2015: Nielson & Powless, 2007). After stimulus presentation there is a post-encoding window, when neural signatures of the stimulus persist even in the absence of direct sensory input (Cohen et al., 2015). In the minutes after encoding, hippocampal cell ensembles appear to replay the sequences of activity which took place during encoding (Diba & Buzsáki, 2007). Stevens, Buckner and Schacter (2010) found memory-predictive correlations in activity in the fusiform gyrus (associated with face perception) between encoding a face and the minutes that followed. The neural reinstatement of recent experiences points to the binding and consolidation of episodic memory (Cohen et al., 2015).

Judd and Rickard (2010) found classical music played after learning a list of words improved later word retrieval (i.e. number of words recalled). While their study did not use a reinstatement paradigm, it illustrates that memory can be enhanced *in the time after the presentation* of to-be-remembered information. The researchers suggested that music's arousal-inducing capacity strengthened the initial flexible memory traces (neuromodulation) to improve recall (Judd & Rickard, 2010). If the encoding (and reactivation processes) of recently formed memories can be enhanced during a post-encoding phase via music, then music played post-encoding may similarly support context reinstatement effects. The underlying rationale is that because brain activity at encoding and post-encoding correspond, the persistent neural signatures, even in the absence of the real stimulus, could be conceptualised as a viable 'item'. We suggest that this 'post-encoding item' might be amenable to binding with a context to form an ensemble just as a 'real' item might. Thus, when a musical context is encountered in a post-encoding time window and then later reinstated at test, context-dependent memory enhancement might be observable.

Music might be uniquely placed to test potential post-encoding enhancement. Music can be played directly following face exposure offset, so is well suited to engage with working memory and post-encoding neural activity. Understanding the mechanisms by which post-encoding systems might modify the formation of memories can play an important part in the development of memory enhancement techniques (Cohen et al., 2015). The ability to use a memory enhancer soon after encountering to-be-remembered information would be valuable in a number of clinical (e.g., people with memory impairments) and non-clinical applied situations (e.g., eyewitness identification).

The Present Study

The present study had two principle objectives. First, to investigate whether background music can improve face recognition through context reinstatement. Second, to examine the temporal parameters of this potential effect. Past research has identified robust context-dependent benefits of background music in the recall of verbal material, however we do not know if these benefits extend to the recognition of nonverbal material, and whether these potential effects can extend into the post-encoding window.

We predicted on the basis of prior research and ICE theory that music can be an enriched contextual environment, which may facilitate the formation of an ensemble through multisensory processing of item and contextual information, to produce a music-related positive context-dependent discrimination benefit. We predicted that reinstating the original musical context at test would allow access to ensemble information, which would activate the appropriate memory trace, strengthening feelings of familiarity, and promoting the correct identification of the target face. This was examined by asking participants to remember faces in a study session with and without background music, then testing their memory via a face recognition test either presented with the same music or with no music. If an ensemble had formed during encoding, then reinstating context should have resulted in increased discriminability (measured by *d'*). However, an increase in both hits and false alarms would suggest music had increased memory strength or general familiarity, but the ability to discriminate between old and new faces had not improved.

Our second research question tested the temporal boundaries of context reinstatement; whether potential reinstatement effects extended to situations where music is played in the post-encoding window. We proposed that music played *after* the presentation of faces might bind with the 'post-encoding item' (persistent neural signatures in the post-encoding window) to form an ensemble, and increase *d'* scores when music was reinstated at test. Furthermore, the intentional ‘holding’ of recently-seen faces in mind during this time would theoretically increase the chances of multisensory working memory integrating the neural signatures of visual information with the present auditory contextual information. An increase in both hits and false alarms would suggest that the neural signals lacked the strength to be sufficiently integrated with present auditory information to form an ensemble. Although not a specific research aim, response bias was also calculated. Past research indicates that individuals shift to more conservative responding when the task is perceived to be more difficult. We suggested that if music increased task difficulty, by imposing additional cognitive load, we might see a conservative-shift effect.

Method

Participants

Thirty participants were recruited from the University of Tasmania. One participant was excluded for not complying with the study instructions. The final sample were 19 females and 10 males, ranging in age from 19 to 47 years (M_{age} = 26 years, *SD*= 8). Ten participants identified as musicians. Participants received either a $20 voucher for their time or academic research credit.

Materials

The experiment was created and delivered via PowerPoint presentation. The presentation was timed and automated. Participants only interacted with the presentation when on-screen instructions indicated to press the space bar to continue (e.g. to see the next face in a recognition test).

Visual stimuli. Visual stimuli were 288 colour photos of anonymous human faces of women (*n* = 144) and men (*n*= 144) with neutral facial expressions, obtained from the Chicago Face Database (Ma, Correll, & Wittenbrink, 2015). The high definition photographs showed each subject's face and neck. Faces were pseudo-randomly (i.e. appearance of randomisation, but pre-determined) assigned across photo arrays and study conditions. Presentation versions were randomised across participants. There were two versions of face presentation: Faces that appeared as target faces in one version, appeared as foils in the second version, and vice versa. Targets and foils were equally distributed across test conditions. For each study trial, eight faces appeared in a 2 x 4 array and were displayed for a total of 20 seconds. The display began with faded (94% transparency) faces for 0.75 seconds. Faces were then illuminated (i.e., appearing un-faded) sequentially (for 1 second each, separated by 0.75 seconds), starting with the first face and then the second, third, fourth, and so on until the last face (Figure 2). All other faces remained faded in the background. After the eighth face, all faces appeared together for three seconds. Total exposure time to the visual face stimuli was twenty seconds.

Figure 2. Face Presentation at Study

The combination of faded and un-faded images was designed so that all faces could remain spatially and temporally present while the music played. Previous pilot testing (*N*= 9) revealed that exposure to the full images (static un-faded faces) for 20 seconds was too easy, leading to very high correct identification rates at test. Reducing the time of face exposure would have increased difficulty but also decreased auditory exposure time and potentially interfered with forming a meaningful item-context ensemble. The use of faded images added task difficulty, while allowing time for participants to create an ensemble. Un-faded images allowed the viewer to get a clear look at facial features, while faded images were harder to see, and thus reduced the ability of the learner to gather further information from their individual facial features. Importantly, this design did not compromise music exposure time or the face's presence (albeit occasionally faded) with the musical context. Similarly, the size of the photo array (eight faces) was chosen so that the task was neither too easy nor too hard, avoiding potential ceiling and floor effects. For image consistency, the computer screens at test were calibrated to 90% brightness and 60% contrast. The presentation order of photo arrays across study trials was counterbalanced across participants by creating multiple versions of the PowerPoint presentation file and varying the order in which photo arrays were displayed.

A 'thinking time' screen appeared for 20 seconds (equal to that of the face exposure time), which represented working memory and post-encoding time. This thinking time allowed for the introduction of contextual music in the post-encoding window (in the relevant conditions). The accompanying screen was dark grey with the words; "hold the faces in memory" in white. A visual noise screen downloaded from the internet was used to erase visual sensory memory after thinking time. The recognition test included all eight old faces and eight new faces.

Filler task. Between study and test sessions, participants worked on a word find for three minutes.

Auditory stimuli. The auditory stimuli consisted of 15 excerpts of classical music (Appendix C, list appears in the legend of Figure 4) that were selected from 21 items via a music rating pilot study. The key musical characteristics and their rationale for inclusion are outlined in the music pilot study (Appendix A). The software *Garageband* was used to create musical excerpts 20 s in length, which were faded in and out to minimise surprise. The music play length was chosen so that it would be long enough for the participants to experience the music, without increasing the face study time unnecessarily and making the recognition test too easy. Music exposure (pseudo-random and individualised across each presentation file) during encoding played synchronously with either the 20 s face presentation or to the 20 s thinking time. Pink noise was used to 'refresh' auditory senses between musical items. Pink noise is made up of all sound frequencies equally distributed across octaves, making it suitable to overwrite the participant's sensory memory for music. Music during the recognition test was set on repeated loop to play across the 16 recognition test slides. Care was taken in the selection and splicing of musical stimuli so that looping the music would appear seamless. Auditory stimuli were delivered via headphones with the volume at 8, which was loud enough to be immersive, but not uncomfortable or disturbing.

Encoding music and test music variables were manipulated between blocks, in a fully factorialised design (Appendix B, Table 1). For encoding music manipulation, faces were presented with no music (control), with music (music), or during "thinking time" (post-encoding). For test music manipulation, the same encoding music was presented or no music.

Procedure

Participants sat in front of a computer screen and put on headphones. Task instructions were delivered through a 'walkthrough' and practice session, enabling participants to get a feel for the length of time for which faces would be visible.

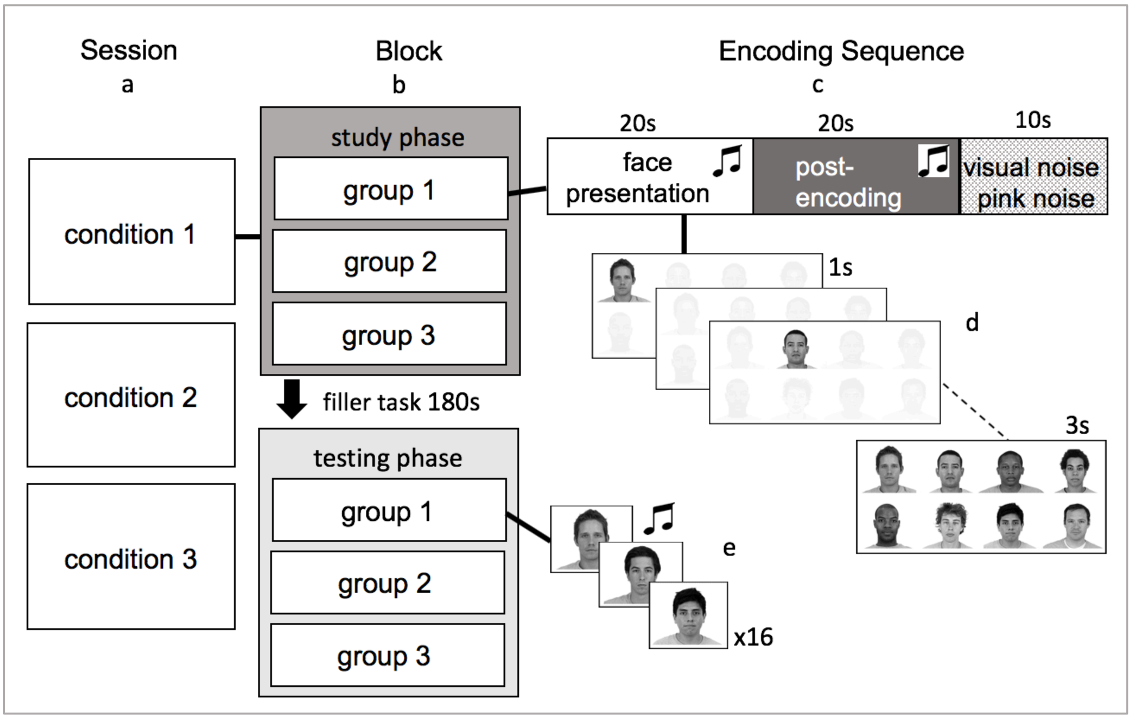

Figure 3. Schematic of the Recognition Task Paradigm

The experimental session (Figure 3, a) was made up of three conditions; control, music present, and post-encoding music. The order of conditions was counterbalanced across participants. Each condition had two blocks (note: Figure 3, b shows only one block as an example). Each block was made up of three encoding groups in the study phase, and three recognition tests in the test phase. In the study phase, participants learned the first group of faces, followed by the second, and then the third group. Based on pilot testing showing that learning a single group of faces resulted in an easy recognition task, learning three groups of faces before testing was designed to increase difficulty and extend the time between learning and test. The total time between learning and testing the same group of faces was five minutes. Faces were presented in an encoding sequence (Figure 3, c) made up of an eight-face array for 20 s (Figure 3, d), followed by 20 s “thinking time” (i.e. to ‘hold’ the faces in memory), followed by a visual noise screen accompanied by pink noise for 10 s.

Participants then worked on a filler task (a word find) for three minutes. Pink noise, played through the headphones, was the signal that the three minutes was up and to start the recognition tests. The test phase was made up of three separate recognition tests (Figure 3, e). Each recognition test comprised of sixteen faces in pseudo-random order, half of which participants had previously seen in the study phase. The group of faces participants had learned first was tested first, then group two faces were tested, then group three faces were tested. Once used, faces did not reappear in any other condition. Test faces were presented sequentially, and participants had to decide whether they had seen each face before by responding *'certain new'*, *'probably new'*, *'probably old'*, and *'certain old'* on a response sheet[2]. There was no time limit to respond.

Following the recognition task (i.e., after completing all of the test blocks), participants completed a short questionnaire. Participants filled in their demographic details in a response booklet; age, sex (male, female, other), and whether they were a musician or not, responding yes or no to the prompt *"I am a musician (I play a musical instrument/ I have played a music instrument/ I sing*)". In addition, participants rated, using a 5-point Likert Scale (from strongly disagree to strongly agree), the following four statements; 1) *The music made it hard to concentrate when memorising the faces*; 2) *The music made it hard to concentrate during the recognition test;* 3) *The music was helpful*; and, 4) *I often listen to music while I work (e.g. studying)*. Questions 1- 3 were included as a way to measure participants' evaluation of task difficulty. Research suggests that learners are conscious of their experience of cognitive load, thus, subjective ratings via self-report questions are

[2] Scaled responses were collected for mixed effects modelling. For our current purpose and simplicity, we collapsed down the four alternative responses to a binary decision (new /old).

useful in measuring mental effort (Pass, van Merriëboer, & Adams, 1994). Question 4 was included to examine whether participants' recognition scores were influenced by their usual work/study environment. Etaugh and Ptasnil (1982) found that students who normally studied to music performed better in a recall test when they learned the material with background music, and students who normally studied in silence performed better when they learned in silence.

Following the task questionnaire participants rated the 15 musical items played in the recognition task in their response book. The task was almost identical to the music pilot study but included 'familiarity' as an extra musical characteristic[3]. This task was included as a cross-validation to corroborate that the music was consistent with the chosen profile.

Total average time of the experimental session (i.e. recognition task, questionnaire, and music task) was 90 minutes. This project was approved by the University of Tasmania Social Sciences Human Research Ethics Committee (reference no: H0012660).

Analysis

Previous context-dependency work has been inconsistent in the measures of recognition performance used. We wanted to use a comprehensive approach, so we used d' (a measure of discrimination) and c (a measure of response bias) to see how context reinstatement affected recognition memory. We also included hit rates (HR) and false alarm rates (FAR) to test specifically for same direction effects (increases

[3] Familiarity ratings were included to be a predictor in a mixed-effects model, but were not analysed as part of this current thesis.

in both HR and FAR), which would indicate increased memory strength for the target, but an inability to discriminate between old and new faces.

The first parameter we measured was *d'*, which is estimated by subtracting the standardised FAR from the standardised HR ($d' = Z_H - Z_{FA}$) and represents the ability to discern between 'old' and 'new' items (for a more detailed explanation see Macmillan, 1993). A value of 0 indicates an inability to distinguish between studied and non-studied faces.

The second parameter we measured was *c,* which reflects the participant's response criterion and is also estimated from HR and FAR. SDT assumes that individuals make memory judgments according to a decision criterion; the point on a decision continuum where an item is judged as "new" or "old". Put simply, some people require more evidence (i.e. stronger feeling of familiarity) than others, or require more evidence in some contexts than others, when deciding whether they have seen a face before or not. The value of *c* is the distance (measured in standard deviations) between the criterion threshold and a neutral point (i.e., neither a yes or no decision is favoured). Negative values signify more 'yes' responses, and positive values signifying more 'no' responses (Snodgrass & Corwin, 1988). *c* is calculated: $c = -(z[H] + z[FA])/2$ (see Macmillan, 1993). Response bias represents different approaches to the task; a conservative criterion is associated with a higher proportion of "new" judgments and sacrifices a high HR for a low FAR. A liberal criterion is associated with more "old" judgements, and sacrifices a low FAR for a higher HR[4].

[4] As per recommendation by Stanislaw and Todorov (1999) we based our calculations of *d'* and *c* on adjusted hit and false alarm rates, to avoid cases where participants produced zero hits or false alarm rates.

Study design

Data analysis consisted of four 3 (music at study; control, music at encoding, music post-encoding) x2 (music at test: control vs. music at test) repeated measures ANOVAs[5] on the outcome variables *d'*, HR, FAR, and *c*. Musician status was entered as a between-subjects factor. Metacognitive ratings were entered as covariates. Effect sizes were calculated using Partial eta^2, which indicates the percentage of variance (and associated error) in each of the effects and interactions, for the omnibus analyses; and Cohen's *d*, with conventional values of d = 0.2, 0.5, and 0.8 corresponding to small, medium, and large effect sizes, for paired comparisons.

Results

Neither musician status[6] nor task ratings[7] interacted significantly with any of our manipulations, so we do not consider them any further in this thesis. Musical characteristics ratings[8] (Appendix C, Figure 4) were similar to those found in pilot testing, cross-validating our musical profile.

Discriminability

The central test for context reinstatement effects is the Study x Test interaction on *d'*. Contrary to our predictions, no interaction was found (Figure 5), $F(1.6,44.3)= 1.06$, $p= .340$, $\eta p^2= .037$. Thus, there was no evidence to suggest that reinstating the music presented at encoding at test improved participants' ability to

[5] Greenhouse-Geiser corrections were made on analyses that included a variable with three levels (i.e. study condition) to avoid violation of the assumption of sphericity.
[6] This is consistent with Lehmann and Seufert (2017), who also found no impact of musical expertise on memory encoding in the presence of classical music.
[7] Task ratings will be explored further using mixed-effects modelling in a follow-up analysis
[8] Music characteristics will be explored further using mixed effects modelling in a follow-up analysis

discern between previously seen and unseen faces. There was also no significant main effect of study condition on *d'*, *F*(*1*.9, 53.2)= 0.67, *p*= .511. ηp^2= .023, (no music: *M*= 1.59, *SD*= 0.45, 95%CI[1.4, 1.8]; with music: *M*= 1.48, *SD*= 0.68, 95%CI[1.2 , 1.7]; music played after face presentation: *M*= 1.57, *SD*= 0.59, 95%CI[1.3, 1.8]). Thus, there was no evidence that the manipulation of music at study affected discrimination. Similarly, there was no significant main effect of test on *d'*, *F*(1,28)= 1.15, *p*= .294, Cohen's *d*= 0.19, 95%CI[-0.18, 0.56], (no music at test: *M*= 1.50, *SD*= 0.61, 95%CI[1.3 ,1.7]; music at test: *M*= 1.59, *SD*= 0.43 , 95%CI[1.4, 1.8]). Thus, there was no evidence that the manipulation of music at test affected discrimination.

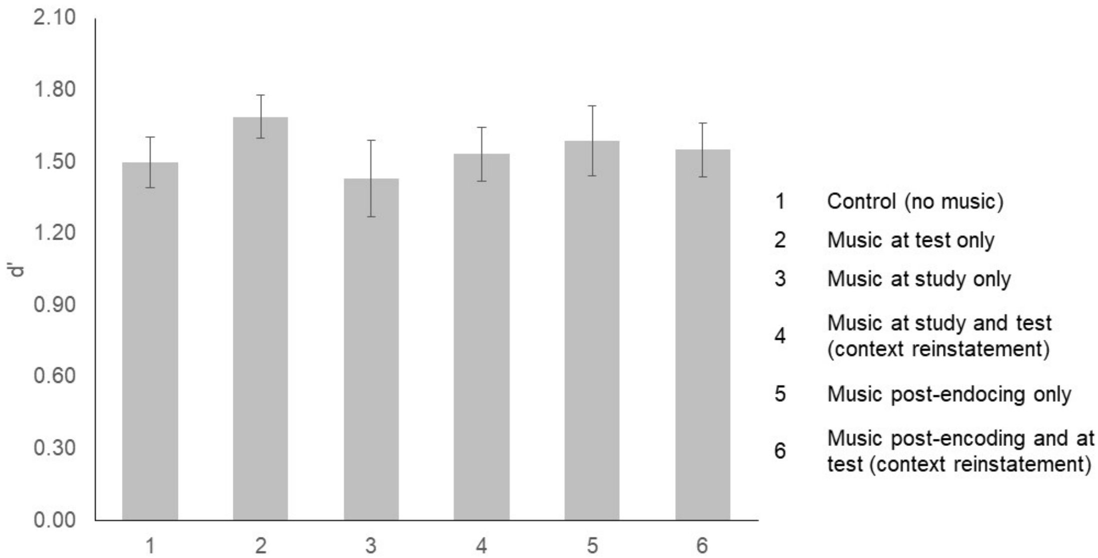

Figure 5. Mean Discriminability (*d'*) for Study and Test Conditions[9]

Following up the non-significant effects of music on *d'*, we ran Bayesian analyses to see if we could find evidence in favour of the null effect. A Bayesian repeated-measures ANOVA returned a BF_{01} of 8.297 for the main effect music at

[9] Note: Error bars indicate standard error.

study on *d'* (indicating that, given the data, the null effect is 8 times more likely than the alternative) and BF_{01} of 157.194 for the model including both main effects and the interaction (indicating the null was 157 times more likely than the model including the critical interaction) (Table 3). In short, these analyses provided evidence that the manipulation of music at study did not affect discrimination, nor did the reinstatement of musical context at test.

Table 2

Bayesian Repeated Measures ANOVA

Model Comparison

Models	P(M)	P(M|data)	BF_M	BF_{01}	error %
Null model (incl. subject)	0.200	0.683	8.638	1.000	
Music at Study	0.200	0.082	0.359	8.297	1.586
Music at Test	0.200	0.207	1.043	3.304	3.547
Music at Study + Music at Test	0.200	0.023	0.094	29.829	1.088
Music at Study + Music at Test + Music at Study ✻ Music at Test	0.200	0.004	0.017	157.194	1.716

Note. All models include subject.

Hit Rate and False Alarm Rate

To further examine musical context on recognition memory, we calculated HR and FAR. All means, standard deviations, and confidence intervals for HR and FAR results are presented in Appendix D (Table 3). We ran two 3 x 2 repeated measures ANOVAs; one on HR and one on FAR. On examination of HR scores we found no significant interaction between study and test conditions, $F(1.6, 45.7)=0.133$, $p= .834$, $\eta p^2= .005$; and no significant main effects of study condition, $F(1.8, 51.2)= 2.50$, $p= .092$, $\eta p^2= .082$, or main effect of test condition, $F(1, 28)= 0.01$, $p= .092$, $\eta p^2= .000$. On examination of FAR scores we found no significant interaction between study and test conditions, $F(1.9, 52)= 2.09$, $p= .137$, $\eta p^2= 0.069$; and no significant main effects of study condition, $F(1.9, 53.9)= 0.12$, $p= .880$, $\eta p^2= 0.004$. However there was a significant main effect of test condition on FAR, $F(1,28)= 13.07$, $p= .001$, Cohens' $d= 0.47$, 95%CI[0.08, 0.86], there were significantly more false alarms when music was played at test (irrespective of whether they heard music or not during study), a result likely confounded by response bias. The absence of Study x Test interactions on HR and FAR was further evidence against a context reinstatement effect.

Response Bias

Response bias was calculated to establish whether background music influenced the participants' placement of their decision criterion threshold, with negative numbers indicating a liberal bias and positive numbers indicating a conservative bias. We ran a 3 x 2 repeated measures ANOVA and found no Study x Test interaction, $F(1.9,53.2)= 1.25$, $p= .293$, $\eta p^2= .043$, (Figure 6.). Also, there was no significant difference between study conditions with no music ($M= 0.03$, $SD= 0.28$, 95%CI[-0.08, 0.14]), with music ($M= 0.12$, $SD= 0.23$, 95%CI[0.03, 0.20]) or music played after face presentation ($M= 0.04$, $SD= 0.26$, 95%CI[-0.06, 0.14]) on bias, $F(1.7, 48.1)= 1.60$, $p= .215$. $\eta p^2= .054$, indicating that response thresholds did not vary according to the presence or absence of music at encoding. However, there was a significant effect of music at test, $F(1,28)= 13.9$, $p= .001$, $\eta p^2= .332$, Cohen's $d= 0.36$, 95%C1[-0.02, 0.7]. Participants became more conservative when music was played during the recognition test ($M= 0.10$, $SD= 0.19$, 95%CI[0.03, 0.18]) compared with no music played at test ($M= 0.025$, $SD= 0.23$, 95%CI[-0.06, 0.11]).

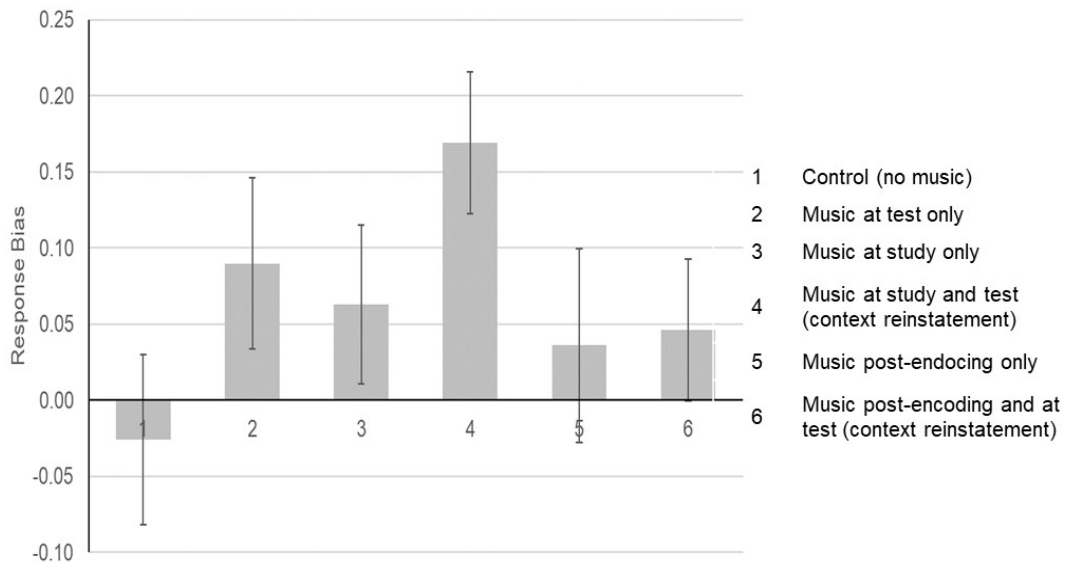

Figure 6. Mean Response Bias (*c*) for Study and Test Conditions[10]

Discussion

The aim of this study was firstly, to examine whether background music can improve face recognition through context reinstatement, and secondly, to investigate whether this potential effect extended to situations where music was played in the post-encoding window. We considered music to be a meaningful context, likely to enrich the encoding of an event and act as an effective memory cue, resulting in a music-related positive context effect (Isarida et al., 2017; Murnane et al., 1999; Smith, 1985). However, background music revealed no context-dependent effect on face recognition discrimination. Therefore, our study did not support the predictions made by ICE theory that an enriched context would support the formation of an ensemble for context-discriminability benefits (Murnane et al., 1999). Additionally, we did not find same direction effects (increases in both hit rate and false alarm rate), thus, reinstatement had not strengthened the memory for the item, or produced general familiarity. Although studies have found reliable context-dependent patterns

[10] Note: Error bars indicate standard error

of results (Smith & Vela, 2001), there has also been a notable lack of context-dependent effects reported in the literature on recognition memory (Godden & Baddeley, 2000; Jäncke et al, 2014). Furthermore, positive findings on verbal items do not necessarily extend to the recognition of complex visual material (e.g.faces). Considering we did not find any background music context-reinstatement effects, it is unsurprising that we did not uncover any music-related advantage in the post-encoding window.

In contrast to Isarida et al.'s (2018b) recent findings, we did not find any benefit in reinstating the original study music during the recognition test. It is difficult to say whether our differing results were due to the type of music played, as Isarida et al. used contemporary music and we used classical music, or whether it was because they used word lists for stimuli (verbal information) and we used faces (visual information). Notably, Isarida et al.'s study only found significant effects for items presented for 2 s or less. Our study's face exposure time was 20 s, therefore, a longer exposure time may have hindered recognition-discrimination effects. Smith (1994) offered an encoding-based explanation for the inconsistencies found in previous recognition studies. According to the overshadowing hypothesis (Smith, 1994), when item information is especially or unusually salient, the surrounding context information may not encode effectively into memory, thus reinstating the context at test is unhelpful. This may have affected our study in two ways. First, the overshadowing hypothesis predicts that long stimulus exposure times lead to the formation of more stable item memories with less dependence on context information (Smith, 1994). According to this perspective, our null reinstatement effect may have occurred from over-exposure to the faces, producing a strong memory trace for the face, eclipsing the need for the musical context to act as a retrieval cue. However, a longer item-context exposure should not necessarily interrupt the formation of an ensemble (Murnane et al., 1999). In fact, ensemble information should be more likely when items are more deeply encoded together. Therefore, the overshadowing principle is not entirely consistent with predictions that ICE Theory may offer for improved recognition performance. This has not been addressed specifically in prior research, so there is an opportunity for further investigation into the boundary conditions of exposure time in context-discrimination through the lens of ICE theory.

Second, and also linked to factors that might overshadow the contribution of contextual information, our method of stimulus presentation may have increased the saliency of the faces at the expense of musical context, diminishing participants' ability to form an ensemble. The visually dynamic presentation, which was specifically designed to associate the faces to the music, may have inadvertently supressed the music, or created a discordant effect. The timing, fundamental to the presentation of the images, created a beat (approximately one face per 2 s) that may have created a disjointed environment when placed with the rhythm of the music. Recently, Isarida et al. (2018a) found that word items that were difficult to associate contextually with their environment showed detrimental effects on context-recall when the encoding environment was reinstated at test. Words were more accurately recalled when they were associated with 'sensible' environments (e.g. photograph of a blackboard, an environment where you would normally find words), compared with 'insensible' environments (e.g. a photograph of a tropical landscape, an environment where you would not normally find words). Our study's dynamic encoding method may have had a similar effect, making it difficult, at least in some cases, to associate the faces contextually with the environment.

While we do not know what effects the face presentation method had on encoding, and whether the musical environment was overshadowed, it is something to be mindful of for future studies. Our presentation was designed to increase task difficulty and avoid ceiling effects, however, another way to increase difficulty is to extend the retention interval between study and test. This was not possible in the present study, due to the already long experimental session (average 90 minutes). We measured immediate memory (five minutes retention interval), however, a future version should measure longer term memory. There is evidence to suggest that context reinstatement is more effective for longer term memory. For example, Smith (1985) found no context dependent effects on immediate memory, but context effects appeared when memory was tested two days later. Indeed, investigating longer term memory would be a natural evolution for any research on potential interventions to improve person recognition. We didn’t find the effects we expected. However, although we think our design met our needs, there is no denying it was idiosyncratic. Thus, we do not take the absence of effects as indicative that the effects will not exist elsewhere. Thus, it is worth investigating further using other paradigms.

Alternatively, it may not have been the amount of study time or retention interval that caused the null effect, but the number of items per context. Rutherford (2004) posits that the presence or absence of context-dependent discrimination during memory retrieval can be explained by cue-overload. The cue-overload hypothesis (Watkins & Watkins, 1975) posits that as the number of items connected to a single cue increase, the less likely it will be able to evoke the target item in a recognition task. Thus, the hypothesis predicts that less overloaded cues increase discriminability, while overloaded cues produce a similar hit and false alarm rate to a control group (Rutherford, 2004). Watkins and Watkins (1975) suggest that a single context is most effective when it is uniquely associated with the one item. In support, Pointer and Bond (1998) found no context effect when a group of words was presented against a one-colour background, but a significant context effect appeared when background colours changed item-to-item (i.e., each item was associated with a single colour background). We applied eight faces to the one context, so the beneficial music context effects were potentially supressed by too many faces associated to the one piece of music. This is consistent with our finding of no observable difference in recognition performance between reinstated and control condition. One face per music item may have resulted in a different outcome. This was not feasible for this project (given the number of participants it would require if we went to a smaller number of trials per participants) but would be achievable in another project (e.g., large scale online study).

A number of explanations have been put forward to account for ambiguous findings in context-recognition studies. Factors such as participant encoding instructions can play a part in determining the size of a context-discrimination effect (Hanczakowski, Zawadzka, & Coote, 2014; Hockley, 2008). Hockley (2008) found when participants were not explicitly instructed to pay attention to the context (i.e., picture backgrounds) during a learning phase, no discrimination effects were observed between previously seen and unseen words in a recognition test. However, when participants were instructed to associate the words with their pictorial backgrounds then this reliably resulted in improved discrimination. Thus, discrimination effects occurred only when instructions emphasised active encoding of item and context (see also, Koen, Aly, Wang, & Yonelinas, 2013; Hanczakowski et al., 2015). Hockley (2008) suggested that item recognition may be dependent on the creation of a strong association between item and context (as also predicted by ICE Theory). Our study informed the participants that their memory for music was not being tested, which may have down-played the importance of the background music. There is strong empirical support for explicit encoding, thus, a simple change in instructions to participants to pay attention to both item and context information may be an easy and effective adjustment to make.

We found that the presence of background music during the recognition test evoked a conservative response bias, suggesting that participants required a higher amount of evidence (i.e. feeling of familiarity) before deciding that a face was old. Notably, Isarida et al. (2018b) measured response bias and found no significant effect, however, they used a different index of bias (β) which may have contributed to the different outcome. Criterion thresholds can change over the course of an experiment in response to task manipulations (Hockley, 2011). Participants also toggle between liberal and conservative responding according to task difficulty (Brown et al., 2007), with a conservative-shift effect predicted when task difficulty increases (Benjamin & Bawa, 2004). Therefore, we tentatively suggest that the task of recognising faces may have been made more difficult by the presence of music at test. Participants may have been able to compensate for any increased difficulty by applying more effort, but not enough to increase recognition accuracy.

However, it is interesting to note that participants' bias did not change according to whether they heard music during encoding. Thus, if this was a difficulty effect, it was selective to increased difficulty related to music at test (cf. music enhancing cognitive load at encoding). It is not entirely clear why this might be the case. Furthermore, participants' average task ratings indicated they did not perceive the music as distracting at test and classified the music as helpful. These ratings reflected the participants' metamemory; their understanding of their own cognitive effort and memory performance. Metamemory is considered an artefact of the memory process (Koriat, 2012), and therefore, differences in memory performance often coincide with changes in metacognitive ratings (Hanczakowski et al., 2015). Considering that on average participants did not perceive the task as more difficult in the presence of music, it is worth considering an alternative explanation (while also acknowledging that metamemory evaluation is not always accurate).

The conservative-shift effect may have been caused by the nature of the music. When listening to music, people tend to experience an increased awareness of their internal states and allow their minds to wander, while inhibiting the neural networks that are involved in monitoring the external environment (Markovic, Kühnis, & Jäncke, 2017). The presence of music may have caused fluctuations in attention (Stanislaw & Todorov, 1992), or induced a more reflective state, which may have translated to more deliberative and cautious responding. At present, this is only conjecture, however, it is an interesting area for further investigation, especially as we currently know little about how individuals are differentially affected by music (Kämpfe, 2011).

Given that we only tested classical music, we cannot claim that music does not offer an effective encoding context. A different choice of music style (especially considering our demographic) may have produced different results (see Isarida et al., 2018b). It seems implausible that every person will be affected in the same way from music (Reaves, Graham, Grahn, Rabannifard, & Duarte, 2016). A piece of music that benefits one person may well have no, or even detrimental effects for another person (Nguyen & Grahn, 2017). According to ICE theory, music must be complex and meaningful if it is to be an effective encoding environment, but this complexity may be the very thing that provides the greatest challenge when investigating whether it can function as an encoding context. Individual differences, such as age, musical taste, and personality trait influence the effects of background music (Küssner, 2017). For example, Furnham and Allass (1999) found detrimental effects of simple (low arousal and repetitive) music on immediate and delayed memory on word recall for introverts, but not for extroverts. We collected individual characteristic ratings for each musical item played during the study, and while these ratings were not evaluated for this thesis, a quick inspection of the ratings shows that a single piece of music can evoke widely varied responses (i.e. the same item is both low and high in pleasantness, depending on the participant). Averaged out, the ratings reflected our desired musical profile, but this potentially underplays the effects on individuals' recognition performances in the presence of individual musical items. This variation will be captured when data are analysed using mixed-effects models.

Integrating and comparing findings on background music and context-reinstatement is made difficult by the diversity of methodologies used in the studies (Murnane & Phelps, 1994). Also, the evaluation of previous research claims has been hindered by the irregular reporting of results; some studies have used only hit rates, which can be confounded by response bias (Proverbio et al, 2015), or evaluated by the number of *associated* items recalled (via 'chunking') (Ferreri et al., 2015). Even Smith and Vela's (2001) meta-analysis on context reinstatement did not indicate what measures they used in their analysis of effect sizes. We would advocate for greater consistency in the measures of memory performance reported.

Specifically, rather than focussing solely on improved hit rates, or overall accuracy, we recommend reporting discriminability and bias, as this measures separately index effects on participants’ ability to discern between old and new items, and effects on the criterion placement (Snodgrass & Corwin, 1988).

In summary, our study did not provide evidence for background music-related context reinstatement benefits for face recognition. Context-dependent recognition presents challenges not faced by context-dependent recall studies (Smith, 1994). With a vast range of inter-individual differences, task complexity, and learning paradigms being tested, combined with a diverse range of music styles, it is unsurprising that music in memory research has provided such a challenge, and led to such contrasting results. An investigation into context effects reveals a list of conflicting results (Smith & Vela, 2001). However, what is clear is that future research will have to disentangle these factors to identify the specific conditions that might lead to recognition improvements. Furthermore, we see many opportunities to extend research from the recognition of faces to person recognition. Increasing our knowledge of music-related memory processes and identifying methods to modify memory to improve an individual’s ability to recognise previously seen people would be worthy in many clinical and non-clinical applied situations. Our study did not find context reinstatement effects, but it has laid a foundation for follow-up studies. Enhancing the recognition of visual information and potential post-encoding benefits are areas where there are many opportunities for future research on context reinstatement.

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Appendix A

Music Pilot study

Prior research has suggested that listening to background music advantages cognitive function via an indirect effect on a person's emotional reactions (Mead & Ball, 2007). According to the arousal-mood hypothesis, background music influences arousal and mood states, and these in turn influence learning (Rauscher, Shaw, & Ky, 1993). Research has found that a positive mood (Husain, Thompson, & Schellenberg, 2002) and a moderate level of arousal (Yerkes & Dodson, 1908) are optimum for learning. These effects are said to persist into the post-encoding memory consolidation phase (Judd & Rickard, 2010; Nielson & Powless, 2007). However, recent reinstatement studies (e.g. Isarida et al., 2017; Lehmann & Seufert, 2017), have failed to find a consistent mediation effect between background music and arousal-mood states on memory performance. In light of recent evidence, our study did not measure participants' arousal-mood states directly. However, the music selection for this study was drawn from items with characteristics previously identified as enhancing cognitive performance: For example, classical pieces that are highly emotional (Proverbio et al., 2015; Rauscher et al., 1993) and pleasant (Balch, Myers, & Papotto, 1999), with a moderate level of arousal (Furnam & Allas, 1999) and a positive mood (Husain et al., 2002). Furthermore, the music did not contain lyrics, as lyrics need to be additionally processed and are thought to drain limited attentional and working memory resources (Lehmann & Seufert, 2017).

Method and Results

Sixteen participants (no demographic details were collected) individually rated 21 musical items on a 7-point Likert scale (low to high) on pleasantness, arousal (energy level), emotionality (emotional tone), and mood (rated positive to negative). Music was presented by PowerPoint presentation on a computer. Music item scores were averaged within each scale. The items selected for use in the main study were items with score averages that best matched the selected musical profile (i.e., high on pleasantness, moderate arousal, moderate to high on emotionality, and positive ratings on mood).

Appendix B

Table 1.

Full List of Experimental Block Types

Encoding music	Test Music
Control (no music)	Yes
	No
Music	Yes
	No
Music post-encoding	Yes
	No

Note: each of the blocks included a within-block manipulation of target-presence at test

Appendix C

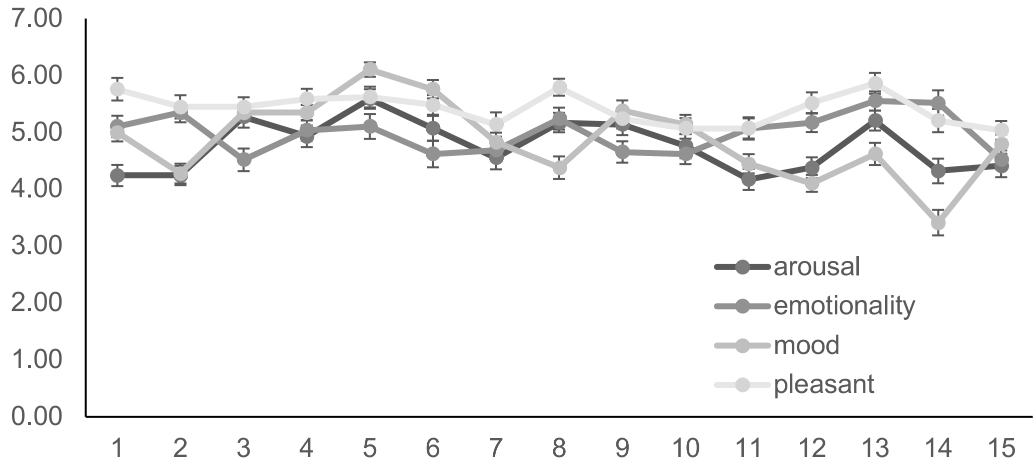

Figure 4. Ratings of Musical Characteristics Across Music Items[11]

Item no.	Musical excerpt
1	Beethoven, L van; Symphony No.6 “Pastorale” (Allegro)
2	Pachelbel, J.; Suite En Sol Majeur
3	Vivaldi, A; Cello Concerto in G major, RV.415 (Musici di San Marco)
4	Mozart, W. A.; Piano concerto no.9 Allegro
5	Vivaldi, A; Concerto 1 in E Spring 1 Allegro
6	Bach, J. S.; Concerto 2 in F Major 2nd Movement- Andante
7	Mozart, W A.; Violin concerto in D Major (Andante)
8	Dvorák, A.; Serenade in E Major, Op. 22:II. Tempo Di Valse
9	Mozart, W. A.; Flute Concerto (Allegro)
10	Vivaldi, Antonio; Concerto Grosso No.5 in A Major, Op.3 (Musici di Zagreb)
11	Haydn, J.; Cello Concerto in D major Hob.VII No:III Allegro
12	Schubert, Franz; Impromptus, Op. 90: No 4 In A-Flat Major. (Allegretto)
13	Bach, J. S.; Suite for Cello Solo. No.1 in G Major. BWV 1007:1. Prélude
14	Mozart, W. A.; Clarinet Concerto in A Major, K. 622 II. Adagio
15	Mozart, W. A.; Piano Sonata No. 21 in C Major. Op. 53 “Waldstein”, III Rhondo.

[11] Descriptions of characteristics given to participants: *Arousal* (from low to high): emotional intensity or energy. Low arousal music is boring or lifeless, whereas high arousal music is dramatic or stirring. *Emotionality* (from low to high): Music low in emotionality is unfeeling or detached, whereas music high in emotionality is moving, touching, or sentimental: *Mood* (from negative to positive): Music that has a negative mood is gloomy or somber, whereas music with a positive mood is cheerful and upbeat. *Pleasantness* (from low to high): Music low in pleasantness is disagreeable, unpleasant, or uncomfortable, whereas music high in pleasantness is agreeable, enjoyable or nice.

Appendix D

Table 3.

Descriptive Statistics of HR and FAR for Study and Test Conditions

	HR			FAR		
	M	*SD*	95% CI	*M*	*SD*	95% CI
no music at study	0.76	0.12	[0.71, 0.80]	0.22	0.09	[0.19, 0.25]
music at study	0.71	0.14	[0.66, 0.76]	0.21	0.1	[0.18, 0.25]
post music at study	0.75	0.13	[0.70, 0.79]	0.22	0.11	[0.18, 0.26]
no music at test	0.74	0.13	[0.69, 0.78]	0.24	0.09	[0.19, 0.26]
music at test	0.74	0.09	[0.70, 0.77]	0.20	0.08	[0.16, 0.22]
control	0.76	0.13	[0.71, 0.80]	0.24	0.08	[0.21, 0.28]
music at test only	0.76	0.12	[0.71, 0.81]	0.19	0.09	[0.15, 0.23]
music at study only	0.71	0.16	[0.65, 0.77]	0.24	0.13	[0.19, 0.29]
music at study and test	0.71	0.14	[0.65, 0.76]	0.18	0.08	[0.16, 0.22]
music at post only	0.74	0.15	[0.68, 0.80]	0.23	0.12	[0.18, 0.27]
music at post and test	0.75	0.12	[0.71, 0.80]	0.22	0.12	[0.17, 0.27]

Appendix E: Participant Information Sheet

UNIVERSITY of TASMANIA

Participant Information Sheet. August 15, 2018

The effects of music on face recognition

1. Invitation

This is an invitation to participate in a study conducted by researchers at the University of Tasmania. Before you decide whether to take part or not, you need to know why the research is being conducted and what it will involve for you. Please take the time to read the following information carefully. If anything is unclear or you would like more information you are welcome to ask. This study is under the supervision of Dr. Jim Sauer (jim.sauer@utas.edu.au)

2. What is the purpose of this study?

The purpose of this research is to investigate the effects of background music on our memory for faces.

3. Why have I been invited to participate?

You have been invited to join this study because you are over eighteen years old. We aim to recruit over thirty people to take part in this study. Participation is voluntary, and there are no consequences if you decide not to take part.

4. What will I be asked to do?

Participation will involve listening to music and completing a series of face recognition tasks in a single 1½ -2hr session in the Psychology Research Centre. You will be asked to memorise groups of faces. Your memory for these faces will be tested in recognition tests. Between memorising faces and the recognition tests you will be asked to work on a simple word find puzzle. Music will play through headphones at various times during the session. The recognition tasks should take between 1¼ - 1½ hours to complete (including breaks). The music and face recognition task will be followed by a short questionnaire and a brief (approximately eight minutes) music task, which involves listening to music and giving subjective ratings on musical characteristics

5. Are there any possible benefits from participation in this study?

First year UTAS psychology students may receive 2 credits (2 hrs) towards their research participation via SONA. Other participants who complete the study are entitled to receive a $20 gift voucher (Coles/Myer).

We will prepare a summary of the results at the conclusion of the study. If you would like to receive this report, please let us know.

UNIVERSITY of TASMANIA

Participant Information Sheet. August 15, 2018

6. Are there any possible risks from participation in this study?

Participation in this research is not anticipated to cause you any psychological or physical distress or discomfort.

7. What if I change my mind during or after the study?

Your involvement in the study is voluntary and you may withdraw your participation at any time, without giving a reason. Your information will be removed from the study files and destroyed.

8. What will happen to the information when this study is over?

All information we collect from you will be kept confidential. Your identity will be preserved by assigning a number to your details. All information will be stored securely on a password protected computer on the University of Tasmania's premises accessed only by the researchers. The information will be kept for five years then destroyed.

9. How will the results of the study be published?

The results of this research may be submitted for publication to scientific journals or presented at conferences. You will not be able to be identified in any reports or publications.

10. What if I have questions about this study?

This study has been approved by the Tasmanian Social Sciences Human Research Ethics Committee. If you have concerns or complaints about the conduct of this study, please contact the Executive Officer of the HREC (Tasmania) Network on +61 3 6226 6254 or email human.ethics@utas.edu.au. The Executive Officer is the person nominated to receive complaints from research participants. Please quote ethics reference number H0012660.

Thank you for your interest in our study.

Appendix F: Participant Consent Form

University of Tasmania

Participant Consent Form Version 1 20/08/18

The effects of music on face recognition

Participant Consent Form

1. I agree to take part in the research study named above.
2. I have read and understood the Information Sheet for this study.
3. The nature and possible effects of the study have been explained to me.
4. I understand that the study involves listening to music and completing some face recognition tasks. I understand that this process will take approximately 1.5 – 2 hours.
5. I understand that participation involves no foreseeable risk(s) to me as a participant in this research study.
6. I understand that all research data will be securely stored on the University of Tasmania premises for five years from the publication of the study results, and will then be destroyed, unless I give permission for my data to be stored in an archive.

   I agree to have my anonymised study data archived.

   Yes ☐ No ☐
7. Any questions that I have asked have been answered to my satisfaction.
8. I understand that the researcher(s) will maintain confidentiality and that any information I supply to the researcher(s) will be used only for the purposes of the research.
9. I understand that the results of the study will be published so that I cannot be identified as a participant.

   Yes ☐ No ☐
10. I understand that my participation is voluntary and that I may withdraw at any time without any effect.

    I understand that I will not be able to withdraw my data after completing the survey as all data has been collected anonymously.

Participant's name: ____

Participant's signature: ____

Date: ______________________

Statement by Investigator

☐ I have explained the project and the implications of participation in it to this volunteer and I believe that the consent is informed and that he/she understands the implications of participation.

If the Investigator has not had an opportunity to talk to participants prior to them participating, the following must be ticked.

☐ The participant has received the Information Sheet where my details have been provided so participants have had the opportunity to contact me prior to consenting to participate in this project.

Investigator's name: ____

Investigator's signature: ____

Date: ________________________